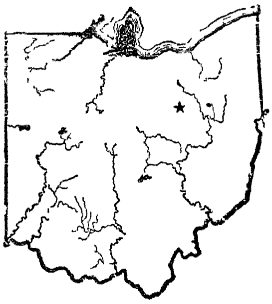
ORCHARD REJUVENATION IN SOUTHEASTERN OHIO

(SECOND REPORT)

OHIO
Agricultural Experiment Station

WOOSTER, OHIO, U. S. A., APRIL, 1920

BULLETIN 339



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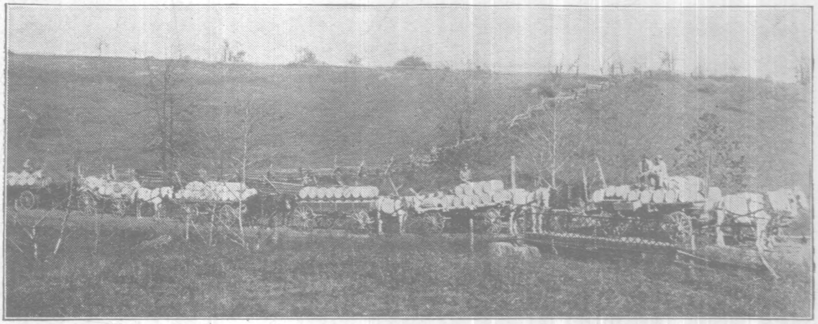

On the way to the shipping station at Vincent. A wagon train of apples from rejuvenated farm orchards in southeastern Ohio.

// BULLETIN

OF THE

Ohio Agricultural Experiment Station

NUMBER 339 APRIL, 1920

ORCHARD REJUVENATION IN SOUTHEASTERN OHIO

F. H BALLOU AND I. P. LEWIS

Former bulletins on orchard rejuvenation work.—The story of the Ohio Experiment Station's orchard rejuvenation work in southeastern Ohio already has been told in former bulletins (Nos. 217, 224 and 240) with a brief recapitulation of these numbers combined with additional data presented in a still later issue—Bulletin 301.

Completion of work and final report; new work for the horticultural department.—However, at the time our more recent bulletin (No. 301) was printed, experimental work was just begun in a small, leased orchard on the Benedict farm near Vincent, in central Washington County. Also there was test work still in progress on the Dyar Farm near the Muskingum River between Marietta and Lowell, which, while so far advanced as to justify discussion at some length in Bulletin 301, was yet developing a few features of interest which are worthy of record. These two experimental orchards were retained for 5 years, and the present bulletin includes final reports of results obtained therein, and is the last one of a series of publications dealing with orchard reclamation work in the southeastern quarter of Ohio. For at least a temporary suspension of this character of service has become imperative because of the establishment of horticultural work at the various county experiment farms now scattered over the State—the supervision of this service, and much of the actual work as well, devolving upon the horticultural department of the Ohio Experiment Station.

Few orchards adaptable to experimental work.—The circumstances responsible for the experiments continuing for 5 years in the Benedict orchard, not being conducted within the same 5-year period in which other finished and reported tests were in progress in Washington and Athens Counties, are perhaps worthy of mention or explanation.

During the Experiment Station's earlier activities in orchard reclamation in southeastern Ohio, numerous farms were visited. To the casual observer, a number readily might have been chosen for experimental purposes, but orchards embracing the essentials of uniformity of surface and soil conditions, of stand, size and condition of trees, and of varieties, were exceedingly difficult to find. We finally found a small orchard located but a short distance north of Vincent, near the Vincent-Barlow-Watertown public highway.

Benedict orchard nearly ideal for cultural and fertilization experiments.—Here was an orchard that immediately interested us; for in all of our scouting over that upland region where thin, poor soil and starving orchards were the rule rather than the exception, this one stood at the head of the list for worn-out soil and low vitality of trees. But it was strong in those essentials of uniformity so pleasing to those who appraise conditions from the experimental viewpoint.

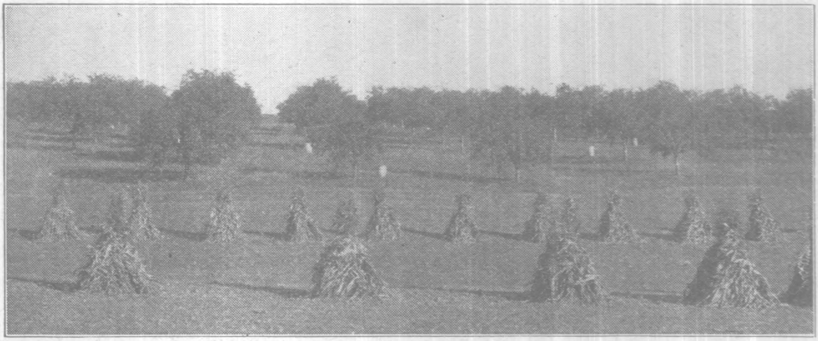

Fig. 1.—View of central part of Benedict orchard near Vincent, Washington County. Two hundred barrels of excellent quality apples had just been harvested at the time this picture was taken in the autumn of 1914, at the close of the first season's work by the Experiment Station.

We found the Benedict orchard situated on a very gentle southern slope—nearly level. Its elevation was less than that of many of the surrounding hills, but there was a broad ravine or little valley immediately southward, the lower level of which was roughly estimated to be 40 or 50 feet below the general level of the orchard. Residents of that section, however, warned us that "the Benedict orchard is one of the coldest spots in all this country;" and "the blossoms in that orchard are killed by late spring frosts every spring."

There was an unusually good stand of trees which varied but slightly in size, although evidently quite small for their age which, by inquiry, was determined to be about 20 years. The foliage throughout the orchard was scant, small and a very pale, yellowish-green color, indicating that the soil was uniformly deficient in nitrogenous plant food. The bodies and larger branches of the trees were covered with lichen and mosses, while the smaller branches and twigs composing the heads of the trees were short, scrubby, mixed with considerable dead wood and upward-slanting—the latter characteristic being a silent evidence that, thus far, there had been no crop to bend downward and fix in curving, drooping position those parts of the trees to which nature assigns the function of fruit-bearing.

The surface of the orchard area was covered thinly with a mixture of native weeds, sedges and poverty grass with which nature clothes such upland soils as have been so persistently tilled and cropped that neither forage nor grain can profitably be produced.

Here, indeed, was an orchard well calculated to quicken the pulse of the most ambitious and venturesome experimenter. For the comparatively level surface of this upland area presented the finest opportunity for a comparison of cultural methods that had been discovered in all southeastern Ohio; while the extremely poor soil conditions and low degree of vigor of the trees afforded ideal opportunities for experiments in the use of fertilizers.

Obstacles temporarily appear.—But disappointment for a time seemed the only reward for our interest and inquiry. The first discouragement overtook us when we learned that the owners resided in Chicago, and were told by those familiar with conditions that there was little likelihood that an arrangement for experimental work could be realized, as the farm was operated under the tenant plan. And with the tenant, for some time, we were unable to make connection.

We were advised, too, by excellent and well-meaning residents of that section that it was worse than useless to attempt to do anything with the Benedict orchard. It was, in short, declared to be an orchard notorious throughout all that region as one with which something was so seriously wrong that its case was hopeless. These good folks were aware and highly appreciative of the Ohio Station's wonderful results in orchard rejuvenation work at various other points in the same part of the State, and we were inclined to suspect they were truly desirous that we should not undertake a case of reclamation the outcome of which might cast a shadow over our record so far achieved. We respected the kindly and sympathetic attitude of these good friends, of course, but their solicitude and well-meant warnings only rendered us doubly desirous of securing the Benedict orchard for experimental purposes. Other resident friends, it is true, were as anxious as we to see what could be accomplished in so unpromising an orchard, and assisted us in every way possible.

A five-year lease secured.—We became acquainted with the tenant or resident manager of the farm, Mr. C. D. Steede, who was a nephew of the owner, Mrs. L. E. Benedict, of Chicago. Mr. Steede assisted us to obtain temporary possession of the orchard by lease. He informed us that it had been of no benefit whatever to him and, furthermore, never had borne but once in its history—a small crop of inferior fruit while the trees were quite young. We were favored in being able to arrange with Mr. Steede for the necessary team work and such other assistance as might be desirable at times in connection with the care of the orchard and the possible harvesting of the fruit. And to Mr. Steede we shall ever be grateful for services conscientiously and cheerfully performed.

Plan of the orchard; experiments outlined; work begun.—The Benedict orchard embraced but two varieties—eight rows of Rome Beauty and four rows of Ben Davis, these rows extending north and south, the long way of the orchard, and each containing sixteen trees.There were, of course, a number of vacancies; but this common defect in old orchards is always taken into account in computing results, and the yields per row or plot are corrected on the basis of average production per tree, so that the figures in completed reports will clearly show comparable totals for uniform or full stands of trees in each plot or division of the orchard.

With the rows of varieties trending north and south, the orchard was divided crosswise into two equal sections extending east and west, each section containing eight rows of 12 trees each, or 96 trees, two-thirds of which were Rome Beauty and the remainder Ben Davis. (See diagram of the Benedict orchard, Fig. 2.) This equal division of the orchard was made for starting a comparison of cultural methods on these unusually uniform and nearly level sections, in which a 5-year period of tillage and growing of cover crops could be compared with an equal period of the grass-mulch plan of orchard management. The southern section, or half, of the orchard was to be plowed early in the spring of 1914, while the northern section, or half, was to remain unbroken, with its sparse covering of mixed weeds, sedges and poverty grass, pending possible vegetative developments from fertilization experiments.

The cultural program for the tillage-cover-crop section, in addition to plowing or disking as early each spring as the ground could readily be worked, was to harrow the land occasionally to keep the surface mellow and free from weed growth, and to sow soybeans or

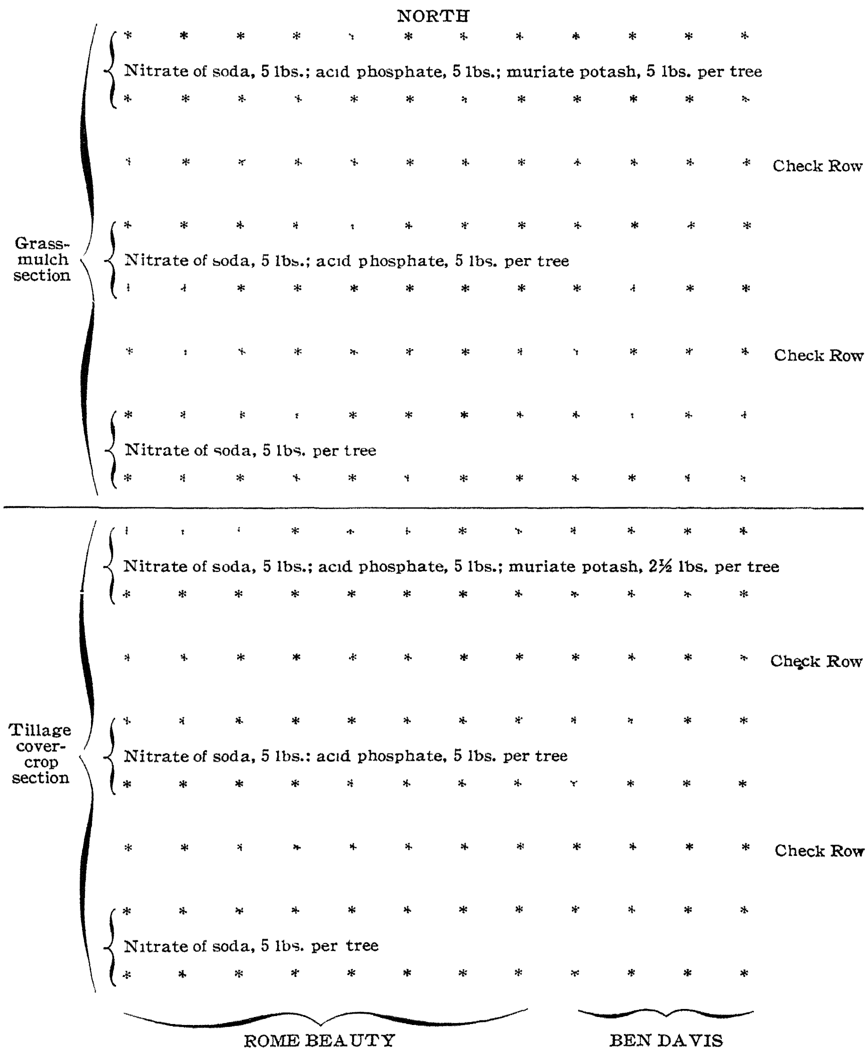

Fig. 2.—Diagram of the Benedict orchard, showing arrangement of plots.

cowpeas early in June. (Fig. 3.) The cover crop was to occupy the ground during the remainder of the growing season and either to be disked down in the autumn, or permitted to stand where it grew until the proper time for tillage the following spring.

Both the tillage-cover-crop and the grass-mulch sections were subdivided into smaller plots for starting a few practical experiments with commercial or chemical forms of plant food under these widely-differing cultural schemes. The plans for fertilization of these two adjoining sections were exactly the same in every detail. In other words the fertilization experiments in the tillage-cover-crop section were to be duplicated without the slightest variation in the grass-mulch section, or vice versa. This subdivision of the cultural sections of the orchard provided for three fertilized plots of two rows each, with a single unfertilized or "check" row left for comparison between each two fertilized plots, in each section. The plan of fertilization is clearly shown in the diagram of the orchard.

Fig. 3.—View in tillage-cover-crop section of Benedict orchard. Soybeans growing as cover crop, sown in June in drills 2 feet apart, and cultivated two or three times during the growing season—especially while plants were small.

A vigorous pruning was one of the initial features of the work of rejuvenation of the Benedict orchard, the dead wood being removed and the thick, scrubby, twiggy heads of the trees well thinned.

The program adopted for the control of insects and fungous diseases was one in which timeliness and thoroughness of spraying should be faithfully observed, the orchard to be treated uniformly throughout each season.

Fertilizers were applied on circular areas of ground beneath the outer extremities of the branches of the trees in the south row of each double-row plot, while the application was made evenly over the entire squares of ground of which the trees were the centers, in the north row of each plot.

The fertilizers were applied by hand on the surface of the ground in both cultural sections, about the middle of April, 1914. The trees, as usual, were exhibiting an inclination to produce a light bloom uniformly over the entire area, and the application of the chemicals was made just as the first pink of the blossom buds was beginning to show. Plowing of the south or tillage-cover-crop section immediately followed fertilization.

Encouraging results soon apparent.—At the height of the blooming period there appeared to be enough blossoms to produce a fair crop of apples; but the flowers were small, and evidently lacking in vitality. In 3 weeks from the date of application of the fertilizers, the petals of the blossoms were done falling.

At this time the first effects of fertilization were clearly noticeable. The blossoms of the fertilized trees had set fruit freely, and the tiny apples were not only of good, rich green color, but clinging tenaciously to the spurs and twigs and growing rapidly. On the other hand a heavy proportion of the blossoms of the unfertilized trees had withered and fallen without setting fruit, while the little apples, formed by those flowers which had proved sufficiently virile to function in a normal way, were much smaller than those on the fertilized trees, and of a pale green, unhealthy color and generally unpromising in appearance. The contrast between the fertilized and unfertilized plots at the end of 3 weeks was quite marked to a trained observer.

The nitrogen provided by the nitrate of soda which was a part of the formula for each fertilized plot, just as it previously had been doing in various other test orchards in southeastern Ohio, was again promptly promoting vigor and fruitfulness. The foliage of the unfertilized trees, too, at the close of the 3-week period was much larger and darker green in color than that of the unfertilized trees; and new shoots were beginning to push out freely and vigorously on the treated trees where, annually, for many years there had been but the discouraged unfolding of clusters or "rosettes" of delicate, yellowish-green leaves, the production of additional single "wrinkles" of new wood representing yearly twig growths, and the premature formation of fruit or wood buds for the succeeding year.

Fig. 4.—Rome Beauties in the Benedict orchard, grading above 95 percent sound fruit. An ordinary padded hand-grading table was used.

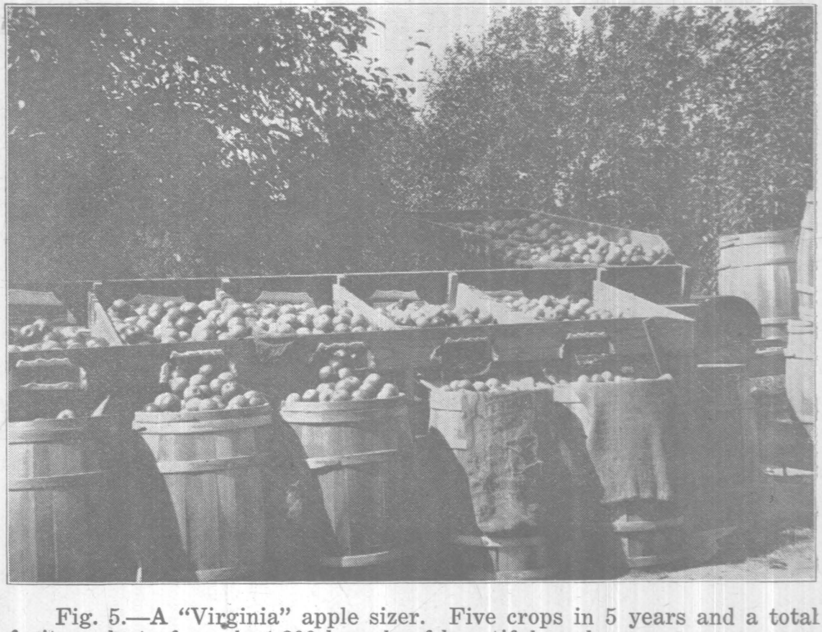

Fig. 5.—A "Virginia" apple sizer. Five crops in 5 years and a total fruit product of nearly 1,200 barrels of beautiful apples.

TABULAR RECORD OF FERTILIZATION EXPERIMENTS AND CULTURE COMPARISONS IN THE BENEDICT ORCHARD, VINCENT, WASHINGTON COUNTY, OHIO

Row No.	CULTIVATED PLOT	1914	1915	1916	1917	1918	5-year average
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
1	Nitrate of soda, 5 lbs. on tree circle	3,309.0	3,316.8	3,134.1	2,801.4	3,539.0	3,220.1
2	Nitrate of soda, 5 lbs. on tree square	2,642.5	3,355.2	3,242.1	3,306.0	2,540.0	3,017,2
3	No fertilizer	1,467.7	3,073.9	2,414.6	2,505.6	1,892.1	2,270.8
4	Nitrate of soda, 5 lbs.; acid phosphate. 5 lbs. on tree circle	2,480.0	3,768.3	2,871 0	2,644.8	3,644.1	3,081.6
5	Nitıate of soda, 5 lbs.; acid phosphate, 5 lbs. on tree square	2,229.3	4,256.4	2,396.7	2,296.8	3,574.0	2,950.6
6	No fertilizer	1,631.5	2,751.3	2,111.8	2,575.2	2,470.0	2,308.0
7	Nitrate of soda, 5 lbs.; acid phosphate, 5 lbs.; muriate of potash, 5 lbs. on tree circle	2,253.4	5,650.5	2,703.4	3,567.0	3,504.0	2,935.7
8	Nitrate of soda, 5 lbs.; acid phosphate, 5 lbs.; muriate of potash, 5 lbs. on tree square.	1,950.0	3,838.1	3,462.4	3,862.8	3,924.4	3,407 5
	Totals for cultivated plot	17,963.4	30,010.5	22,336.1	23,559.6	25 087.6	23,791.5

Row No.	GRASS-MULCH PLOT	1914	1915	1916	1917	1918	5-year average
		Lbs.	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*
9	Nitrate of soda, 5 lbs. on tree circle	1,344.6	4,767.6	2,203.4	3,636.6	2,137.4	2,817.9
10	Nitrate of soda. 5 lbs. on tree square	1,605.3	3,291.7	1,325.5	2,852.6	2,402.2	2,295.5
11	No fertilizer	1,652.1	1,003.8	1,734.6	1,131.0	1,997.2	1,503.7
12	Nitrate of soda, 5 lbs.; acid phosphate, 5 lbs. on tree circle	3,178.0	4,377.8	2,730.0	4,297.8	4,415.0	3,799.7
13	Nitrate of soda, 5 lbs.; acid phosphate, 5 lbs. on tree square	3,111.8	3,265.8	3,130.5	3,828.0	4,870.5	3,641.3
14	No fertilizer	1,301.1	2,067.3	1,501.0	2,035.8	1,962.2	1,773.5
15	Nitrate of soda, 5 lbs.; acid phosphate, 5 lbs.; muriate of potash, 5 lbs. on tree circle	2,309.8	3,799.8	2,752.1	3,984.6	3,591.6	3,287.6
16	Nitrate of soda, 5 lbs.; acid phosphate, 5 lbs.; muriate of potash, 5 lbs. on tree square.	4,292.4	2,731.8	3,005.7	3,619.2	5,606.4	3,851.1
	Totals for grass-mulch plot	18,795.1	25 305.6	18 382.8	25 385.6	26,982.5	22 970.3

Note.—Referring to the data recorded in the second and fourth lines of this table, it should be borne in mind that the unfertilized trees in the grass-mulch section have received neither fertilization nor cultural treatment, therefore, cannot be fairly compared with the unfertilized trees in culture section.

The early springtime promise of beneficial results from fertilization was intensified as the season advanced. The fertilized plots were briskly rounding into "business form." As proof that this improvement was not imaginary it may be stated that the orchard produced more than 200 barrels of sound apples this first season as a reward for the initial rejuvenative care bestowed upon it. (Figs. 4 and 5.) And this result proved to be the beginning of a period of remarkable thrift and fruitfulness. For five successive, generous crops of excellent apples were produced in the period the orchard was under the control of the horticultural department of the Ohio Experiment Station. It has many more years of generous fruit production ahead, providing it be annually cared for as during the period of experimentation.

Details of results in the Benedict orchard.—Inasmuch as the following tables, comment thereon and the final summary render unnecessary further general discussion of the work done and the results obtained in the Benedict orchard, the attention of the reader is directed to the data presented on succeeding pages. And the writer feels quite justified in the assertion that no single piece of experimental work undertaken by the horticultural department of the Ohio Experiment Station during the past 10 years' activities in orchard rejuvenation service has produced data that dependably answer so many orchard improvement queries as has the work in the Benedict orchard. (Fig. 6.)

AVERAGE YIELDS PER TREE UNDER THE VARIOUS CONDITIONS AFFORDED BY THE CULTURAL AND FERTILIZATION EXPERIMENTS IN THE BENEDICT ORCHARD

Av. per tree per yr., for 5 yrs., all fertilized trees in culture plot......266.7 lbs.
Av. per tree per yr., for 5 yrs., all unfertilized trees in culture plot...193.0 lbs.
Av. per tree per yr., for 5 yrs., all fertilized trees in gr.-mulch plot...273.5 lbs.
Av. per tree per yr., for 5 yrs., all unfertilized trees in gr.-mulch plot..136.3 lbs.

CULTIVATION VS. GRASS-MULCH TEST IN THE BENEDICT ORCHARD

Yields of apples, cost and financial returns per acre per year, for the years 1914-'15-'16-'17-'18

	Average yield per acre per year	Value of crop per acre per year	Cost of cultivation per acre per year	Net returns per acre per year
	Barrels	*Dollars*	*Dollars*	*Dollars*
Cultivated and fertilized...........	73.5	235.20	17.09*	218.11
Grass-mulch and fertilized	75.4	241.28	2.65	238.63
Cultivated and unfertilized..........	53.2	170.24	17.09	153.15
Grass-mulch and unfertilized..	37.6	120.32	2.65	117.67

*The cost of cultivation includes plowing or disking, harrowing, seed, seeding, cultivation of cover-crop and disking down of same in autumn. The cost of cultural work in the grass-mulch section includes clipping the grass with mowing machine in June and September, and trimming with scythe around and beneath the trees.

The data contained in the table given above embrace dependable answers to a number of questions which are being constantly asked by those interested in apple orchard reclamation or improvement. Let us briefly analyze the more important points the figures present:

Comparison of cultural systems.—Doubtless the feature of the table that will first claim attention is the result of the 5 years' comparison of the tillage-cover-crop system with the grass-mulch method of orchard culture, in which the various plots in each of the

Fig. 6.—Production of two rows of Rome Beauty containing eight trees each (1914). Row at right, fertilized for first time in April, 1914, yielded 21 barrels; row at left, unfertilized, 9 barrels.

two sections were fertilized exactly the same. Here it will be discovered that the difference in yields of fruit obtained by these two cultural schemes so unlike in their character is very small—amounting to slightly less than 2 barrels per acre per year in favor of the grass-mulch plan. This contest of methods was extremely close throughout the period of the test, so far as apple production was concerned; but the cost of the tillage-cover-crop system being more than six times as great, there was an eventual gain of $20.52 per acre per year for the grass-mulch method.

There was not a time during the 5 years' test that seasonable orchard work could not be performed in the grass-mulch section on a firm and cleanly footing, and with comfort and satisfaction; which by no means can be stated with truthfulness concerning seasonable work in the section annually under tillage and culture.

The apples produced in the grass-mulch section were slightly smaller in size, but firmer, more highly-colored and superior in keeping quality, as compared with the fruit from the tillage-cover-crop section. The apples in the latter division of the orchard, however, were very fine, sound and attractive.

The next comparison that logically follows is that of the tillage-cover-crop system with the grass-mulch plan where no fertilization has been done in either section. Here we find that tillage and cover-cropping alone have increased fruit production at the rate of 15.6 barrels or $35.48, net proceeds, per acre per year, for the 5-year period. However, this is a comparison that is clearly unfair; for the unfertilized trees in the tillage-cover-crop section have been benefited from the rejuvenative effects of cultivation, while the unfertilized trees in the grass-mulch section have had neither additional plant food nor culture of any description, but have simply been forced to remain in their former state of neglect and starvation, with the exception of the lime-sulphur spraying which was applied uniformly over the entire orchard. This comparison, therefore, is given merely as a matter of interest and to answer a question that is almost certain to form in the mind of the reader.

All who are familiar with orchard rejuvenation work where thin, poor soil conditions prevail, are aware that plowing of orchard land that has long lain in grass exerts an influence similar to that of the application of nitrogenous plant food, if cover crops are sown and grown and all vegetable matter thus produced be turned back into the soil. We have heard the statement ventured by orchard cultivation enthusiasts, that annual tillage and cover-cropping alone, where the land is sufficiently level, will return fully as fruitful and satisfactory results as the grass-mulch practice where expensive nitrogenous plant food is applied annually. Is this true? It may be, under certain conditions, but not under the poor soil conditions of the upland section of southern Ohio. Our 5-year trial of the above stated proposition, on the humus and fertility-depleted orchard land at Vincent, shows that the grass-mulch plan of culture plus fertilization with quickly-available nitrogenous plant food gave a gain of 22.2 barrels of apples, or a net cash gain of $71.48 per acre per year, over the tillage-cover-crop system without fertilization, after deducting the cost of fertilization at the allowance of 35 cents per tree or $14 per acre per year.

The cost of the grass-mulch method of culture, plus the cost of fertilization with the standard 5-5-2½ pounds per tree per year, nitrate, phosphate, potash formula, respectively, totals 44 cents per acre less than the annual cost of the tillage-cover-crop scheme.

A fourth comparison was made to determine to what extent cultivated plots in the tillage-cover-crop section might be benefited by fertilization. This test resulted in a gain of 20.3 barrels of apples, or a net cash gain of $50.96 per acre per year for the 5-year period as compared with the unfertilized plots under tillage.

A similar comparison wholly within the grass-mulch section was possible, resulting in a gain of 37.8 barrels of apples, or a net cash gain of $106.96 per acre per year, for the fertilized plots as compared with those receiving no fertilizer.

COMPARISON OF RESULTS OF APPLICATION OF FERTILIZERS TO CIRCULAR AREAS BENEATH THE SPREAD OF BRANCHES OF THE TREES, WITH APPLICATION TO THE ENTIRE TREE-SQUARES OF GROUND, FOR A 5-YEAR PERIOD

Manner of applying fertilizer	Yield in tillage section		Yield in grass-mulch section	
	Apples per tree per year	Apples per acre per year	Apples per tree per year	Apples per acre per year
	Pounds	*Barrels*	*Pounds*	*Barrels*
On tree-circles	273.2	75.3	275.1	75.8
On tree-squares	260.4	71.8	271.8	74.9
Gain for circular applications	12.8	3.5	3.3	0.9

These results of concentration of fertilizers on circles beneath the spread of branches, while indicating a small margin of gain as compared with the application over the full tree-squares of ground, should not be considered of much importance so far as the fruit product is concerned. The difference in results of the two methods of application is really too small to take into account. Moreover, in certain individual plot comparisons, the tree-square or "all-over" fertilization gave the greater yields. The fact that really is worthy of attention is that by applying the fertilizer evenly over the entire tree-squares, a greatly increased production of grass may be obtained. This vegetation is utilized as a mulch or soil covering for the ground that produces it—the grass being allowed to lie where it falls when cut with the mowing machine.

Peculiar effects of chemical fertilization on native plant life.— In former bulletins of this series, the writer has described and illustrated the transforming influence on natural field vegetation where, without sowing seeds of any kind, chemical plant foods were applied as surface dressings to thin grass land. It was during the course of this work that was first brought to notice in a striking way the following surprising points: (1) That the application of quickly-available nitrogenous plant food under the conditions just described, would speedily develop a dense soil covering of the more valuable grasses such as timothy, redtop, bluegrass and, in some cases, orchard grass (no clover) where formerly nothing but a sparse covering of mixed weeds and poverty grass and sedges existed. (2) That, under similar conditions, successive, annual applications of promptly-available phosphorus exerted an almost equally wonderful influence in promoting a development of legumes, especially red and white clover (no grasses). (3) That where a combination of promptly-available nitrogen and phosphorus (carried in nitrate of soda and acid phosphate) in equal proportions and moderate quantity, was applied under the conditions described, a mixture of grasses and clover soon entirely crowded out the formerly prevailing sparse soil covering of mixed weeds, sedges and poverty grass.

PRODUCTION OF MULCH MATERIAL BY FERTILIZATION IN THE BENEDICT ORCHARD

Comparison of "all-over" fertilization with no fertilization, for the years 1915-'16-'17-'18

	Per tree square	Per acre	Per tree square	Per acre
	Nitrate soda 200 lbs. per acre Acid phos. 200 lbs. per acre		Unfertilized	
	Pounds	*Pounds*	*Pounds*	*Pounds*
1915 yield of vegetation	38.7	1,548	4.0	160
1916 yield of vegetation	66.6	2,664	16.8	672
1917 yield of vegetation	52.6	2,104	12.1	484
1918 yield of vegetation	48.8	1,952	11.8	472
Total for 4 years	206.7	8,268	44.7	1,788
Average per year	51.6	2,067	11.1	447

In none of our preceding orchard fertilization experiments were these new and interesting phenomena more clearly displayed than in the Benedict orchard at Vincent, as the figures presented in the table readily indicate. In 1914, a casual examination of the mixed vegetation thinly covering the orchard area embraced in the section devoted to grass-mulch culture revealed golden-rod, fleabane or white-weed, ox-eye or field daisy, poverty grass and broom-sedge. Among these more dominant forms of vegetation could be found very small, scattering plants of a number of species of the better grasses and of white and red clover. However, because of the lack of plant food necessary to the normal development and multiplication of these more valuable forms of vegetation, they were so tiny and so diffcultly seen that their presence would not have been suspected at all by a not especially interested observer.

The use of 5 pounds per tree, or 200 pounds per acre per year, each of nitrate of soda and acid phosphate, quickly spread a dense carpeting of timothy, redtop and white clover over the plots of ground thus treated. (Fig. 7.) On the plots from which the acid phosphate was omitted the white clover was missing, but the grasses were abundant.

As in practically all other of the upland sections of Ohio where poor soil abounds, broom sedge in recent years had been gaining possession of ever-increasing areas of the grass or pasture land and abandoned fields in the southeastern part of the State. Mindful of those who may be unfamiliar with this "poor soil plant" it may be well to explain that attached to each one of the abundantly-produced seeds is a tiny tuft of downy filaments. These seeds when detached from the parent plants by the shifting winds are scattered widely over the surrounding land. A single small group or clump of plants will thinly but effectively seed a considerable area, and the resulting widely-scattered plants, in turn, will soon thickly seed the intervening spaces. (Figs. 8 and 9.)

At the beginning of cultural and fertilization operations in the Benedict orchard, broom-sedge was not only invading and luxuriating in surrounding fields, but was becoming well sprinkled throughout the section of the orchard devoted to the grass-mulch method of culture. It continued to thrive and thicken in the unfertilized plots until its possession of these poor, untreated parts of the orchard was almost undisputed even by the hardy, aggressive, persistent golden-rod and ox-eye daisies. However, its spread was abruptly and strikingly checked at the straight margins of the fertilized plots—especially those plots treated with nitrate of soda and acid phosphate at the rate of 200 pounds of each per acre per year. In autumn of the third season's progress of the work in the Benedict orchard the casual, uninformed observer would have been led to decide that the fertilized plots had been clipped with a mowing machine, while the check or unfertilized plots had been allowed to remain unclipped with the season's growth of sedge standing upright—so straight and clean-cut was the line of demarkation between the fertilized and unfertilized plots. The fact was, however, that neither the fertilized nor unfertilized plots had been clipped since June. The aftermath carpeting of the fertilized plots, as before stated, was composed of white clover, timothy, redtop and

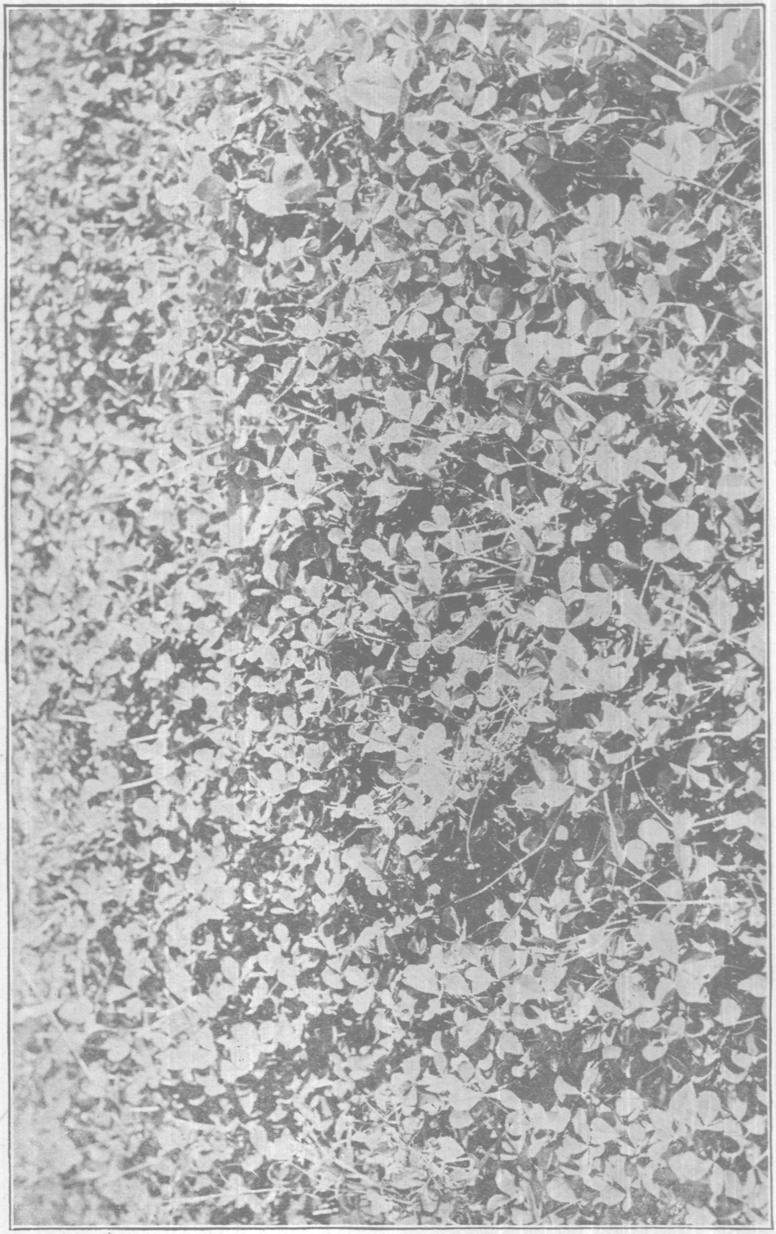

Fig. 7.—A close view in fertilized plot showing white clover.

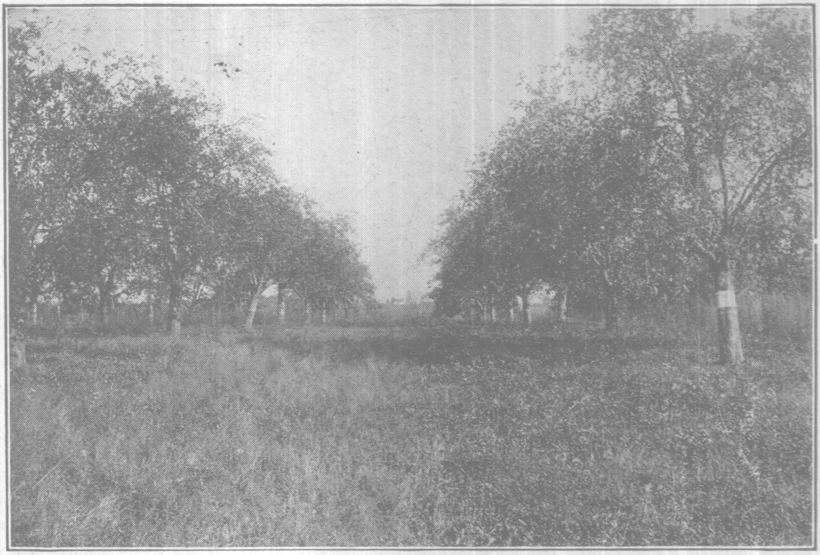

Fig. 8.—Division line between fertilized and unfertilized Rome Beauty plots in Benedict orchard, at the close of the second season's work (1915). In the fertilized plot at the right is a dense mass of white clover mixed with bluegrass, redtop and some timothy. The unfertilized plot at the left remains thinly covered with mixed native weeds and poverty grass; also many young plants of broom-sedge are showing. No seeding.

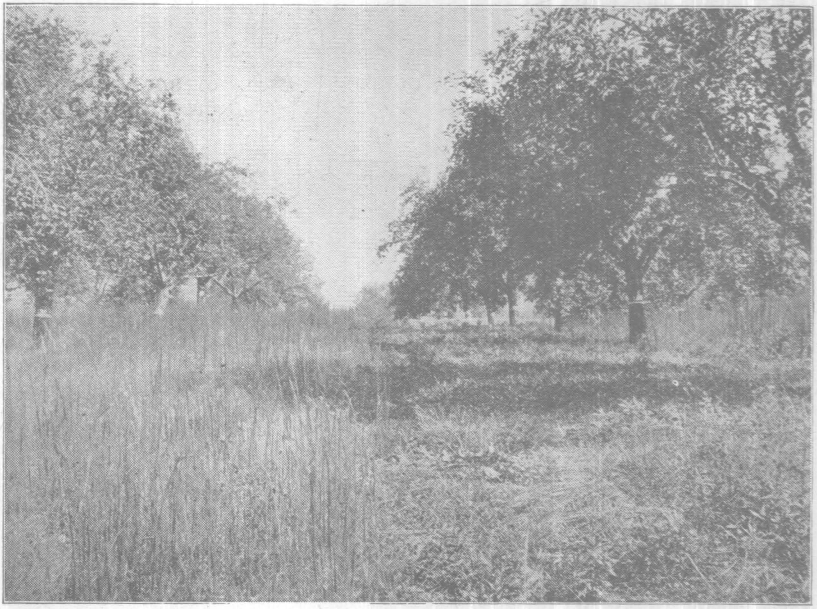

Fig. 9.—Same plots as shown in Fig. 8, one year later. Broom-sedge has densely invaded the unfertilized plot, but has not crossed over the plot boundary line into the fertilized plot which is now thickly matted with white clover and an aftermath of mixed grasses. These two plots had been clipped with the mowing machine the same day in June.

bluegrass—a combination which, without sowing seed, had crowded out practically all of the coarser forms of vegetation commonly occupying poor soils in that region. The general appearance of these fertilized and unfertilized plots is fairly well shown in Fig. 9.

FINAL REPORT ON ORCHARD REJUVENATION WORK AT LOWELL, OHIO

Observations on orchard rejuvenation work.—Preliminary reports already have been issued (Bulletins 240 and 301) relating to the orchard fertilization experiments conducted for a number of years on the farm of M. H. Dyar & Son, Lowell, Ohio. These somewhat varied tests having been concluded on account of pressure of other horticultural service in connection with the several county experiment farms of Ohio, a brief final report is made covering the more important data obtained, and including a concise summary of such results as may clearly and helpfully answer a number of questions such as are constantly being asked by owners of neglected, unfruitful apple orchards.

In addition, in this final presentation of results of the Ohio Experiment Station's activities in restoration of the lost industry of apple production in southeastern Ohio, the writer takes the liberty of briefly discussing a certain phase of work of this character which, if not often overlooked entirely in the pursuit of scientific data, is rarely mentioned in printed reports of such investigations. We refer to the true results of experimental work—those results which, aside from being set forth in statistical tables of formulas, yields, gains, losses, percentages, and technical comment, may be measured in simple terms which denote the solution of some of the problems of rural life in a rugged, diffcultly-tilled, thin-soiled region.

Sharp-angled, naked facts and outstanding figures indicating degrees of success or failure of various tests in carefully conducted research work truly have their place and mission, and their importance is fully recognized; but, unless those same facts and figures convey or are accompanied by a message of helpfulness to those for whom the work is, or should be, primarily and especially planned, the whole undertaking deserves to be considered a failure. However, if the data obtained—no matter how tersely and technically recorded—have origin in practical, interesting, encouraging and inspiring object lessons in orchard, field or garden, clearly and sympathetically interpreted, the results will surely repay all effort, time and expense incurred in experimentation.

In proof of these observations there is a fitting illustration afforded by the formerly unfruitful, lightly-valued, "pasture-land" orchard that is the subject of this division of our present report on orchard rejuvenation. For the facts in connection with the reclamation of the Dyar orchard constitute one of the most interesting farm stories which developed during the Ohio Experiment Station's decade of investigations and horticultural service in southeastern Ohio. (Figs. 10 and 11.)

The story of the Dyar orchard.—The Dyar orchard in which fertilization experiments were conducted is located between Marietta and Lowell, on a partly level hilltop, at an elevation of about 300 feet above the level of the adjacent Muskingum River and valley. The level portion of this hilltop being the most easily tilled field on the rugged farm which had been in possession of the Dyar family for nearly a century, had been utilized in production of grain and forage as long as such crops could be grown in sufficient quantity to justify the time, labor and seed necessary for continued tillage, culture and cropping. When farming eventually became a losing industry because of thin, impoverished soil conditions, the ground was planted to apple trees.

At the time of our first acquaintance with the Dyar farm, in late autumn of the year 1909, we found the following conditions: (1) An orchard that was of such age that it should have been in profitable bearing for a number of years—but had not yet borne a single bushel of sound, salable fruit; (2) that the 30-acre orchard tract (cut off from the remainder of the farm by the Marietta-Lowell public highway or "Ridge Road" was being offered for sale at the price of $30 per acre; (3) that the orchard land was considered and utilized by the owner only as sheep pasture—and thin grazing at that; (4) that while the trees were fairly uniform in size—of such size as to be producing an abundance of fruit—they were very low in vigor as indicated by their small, yellowish-green foliage and short twig growths, and were practically barren.

An excellent opportunity for experimental work in orchard fertilization was presented in the Dyar orchard and, after a season or two of preliminary spraying tests, such work was planned and set in operation. It was decided by the owner that this orchard tract should be withdrawn from the open market for real estate, temporarily at least—a market in which the demand for property of that particular character seemed peculiarly inactive at that time. Naturally such evidence of truly-awakened interest in the scheme of orchard rejuvenation on the part of Mr. Dyar was gratifying to the experiment station representatives.

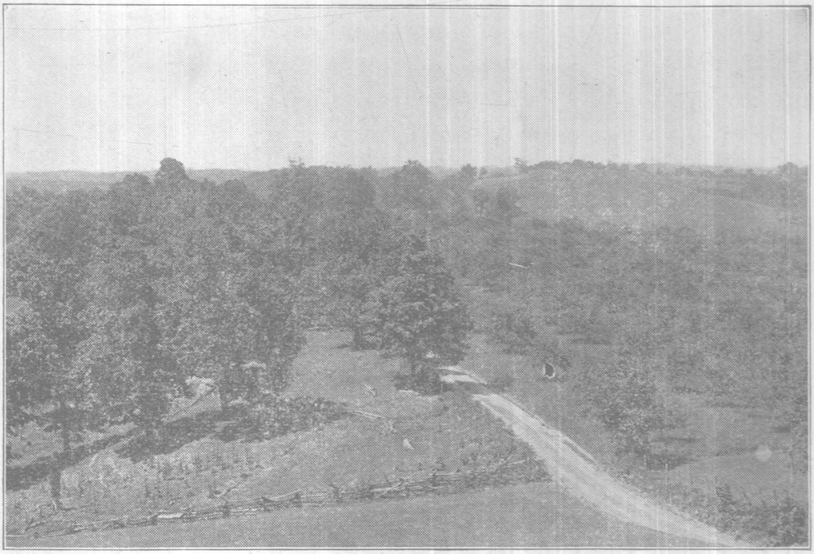

Fig. 10.—A corner of the orchard of M. H. Dyar & Son, Lowell, Washington County, in which experiments were conducted by the Ohio Experiment Station. The highway shown in the picture is known as the "Ridge Road" between Marietta and Lowell.

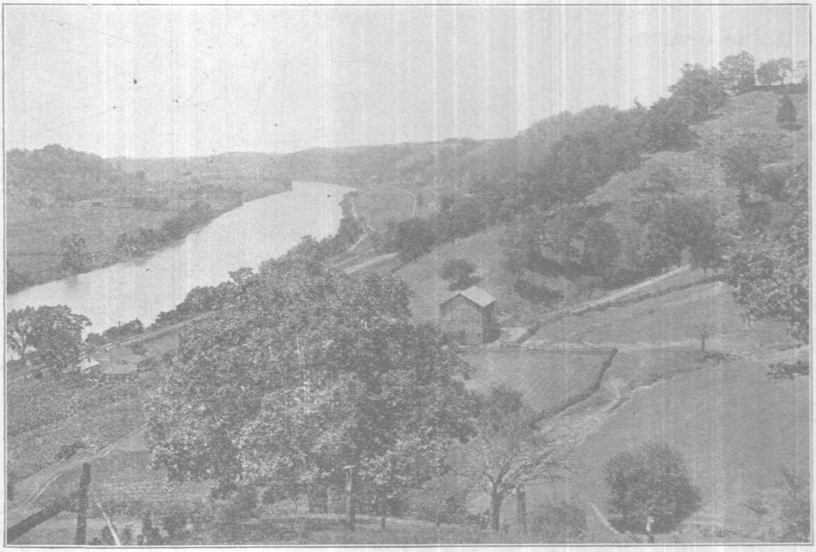

Fig. 11.—This is a view continuing to the left of that presented in Fig. 10, showing the ruggedness of the Dyar farm, the century-old Dyar homestead down by the river side, and a splendid sweep of the Muskingum Valley, looking toward Lowell beyond the distant hills to the left.

Soon there appeared at the edge of the once-abandoned, unfruitful orchard, near the public highway, a conspicuous sign acquainting travelers that they were passing "Riverside Fruit Farm," the property of M. H. Dyar & Son. (Fig. 12.) It was good reading —that sign along the highway. Between the letters and the lines of that neatly-painted, home-made sign, we could read a wonderful and beautiful farm story; a story of reclamation of a lost industry; a story of the happy solution of long existing and, at times, discouraging financial problems in connection with the steep old farm along the bluffs of the Muskingum; a story of discovery of an agreeable, satisfying and profitable business at home.

Fig. 12.—"It was good reading—that sign along the highway. * * * * For between the letters and the lines of that neatly-painted, home-made sign, we could read a wonderful and beautiful farm story."

The great flood of March, 1913, seriously damaged the century-old home of the Dyars. The dwelling stood at the base of the great hill, near the edge of the river and had been supposed to be safely above the flood-line of the stream. To attempt to repair the extensive damage to an already very old structure, promised to be not only expensive, but at the same time an unsatisfactory undertaking.

The destruction of their home under different circumstances would have been little short of a calamity to the good Dyar family, but already they had witnessed highly-encouraging evidence of new life stirring in the bodies, branches, twigs and buds of the great orchard on the hilltop—life and vigor and promise of abundant fruitfulness that in a great measure alleviated the seriousness of the catastrophe that had cost them their old home. There had been a splendid crop of sound and perfect Grimes Golden apples in the initial spray- and culture-test plots in 1912. Indeed, to indulge in a single interesting detail in this connection, it may be stated that a half-acre test plot well sprayed and cultivated, produced at the rate of 890 bushels per acre in the 1912 season, as well as smaller crops of equally fine fruit in the preceding seasons of 1910 and 1911.

Hence it was with enthusiasm and confident assurance born of new-found faith in their now highly-valued orchards, that a new home was thoughtfully planned and built on much higher ground. Modern, spacious, attractive, homelike and with many conveniences that characterize the better class of city dwellings, this charming home from its eminence of safety commands a superb view of the Muskingum River and level valley beyond. And it stands as a substantial monument to the rejuvenated orchard far above on the hillcrest. (Figs. 13 and 14.)

Our description of the Dyar orchard and its wonderful development from mere pasture-land service and valuation to a generous income-producing, home-building department of that rugged farm which for the most part "stands on edge" along the east bank of Muskingum, should not be construed into self praise for the horticultural department of the Ohio Experiment Station. Not by any means. A series of test plots embracing but about one-tenth of the orchard area were planned by the experiment station representatives and cared for co-operatively by the department and the owners. These object lessons in orchard reclamation were provided not alone for the owners of the orchard, but for neighboring orchard owners. It was the practical use that the Dyars made of the object lessons available in those test plots that brought to them success, two new homes, farm improvements and prosperity. For the lessons observed in the experimental one-tenth of their orchard were promptly and confidently applied to the surrounding nine-tenths.

Nor did the fruitfulness and profitableness of this orchard decline in the least when the period of experimentation necessarily had to be terminated by the Experiment Station. The yields of excellent fruit are growing more and more abundant as the trees rapidly increase in size and vigor under the liberal feeding and excellent care given them. The yield of fruit the past season of

Fig. 13.—The "Old and the New" at Riverside. The quaint little dwelling shown in the small insert is the century-old homestead of the Dyar family, while the new home represents the substantial "first fruit" of the rejuvenated orchard back on the hilltop.

A second modern residence—the new home of Dwight R. Dyar, the junior member of the firm—recently has been built 160 feet to the left of the new home above shown.

Fig. 14.—Hauling apples down the "mountain roadway" from the Dyar orchard to the electric railway siding that has been built at "Riverside Fruit Farm" near the residence and farm buildings for the purpose of convenient loading of the apple crops.

1918 was nearly 3,000 barrels for the 30 acres—the same 30 acres which could have been purchased previous to the year 1910 for $900.

The Dyar orchard is but a single illustration of the progress made in orchard reclamation throughout southeastern Ohio during the past 10 years. On a similar scale hundreds of other orchards and their respective discouraged owners have been benefited by the campaign of orchard reclamation inaugurated by the Ohio Experiment Station in 1909 and continued to the close of the season of 1918.

Fertilizer tests in the orchard of M. H. Dyar & Son, Lowell, Ohio, 1912-1917.—The results show the use of different elements and quantities of commercial plant food in the production of apples and vegetation for mulching, when such plant foods are applied as surface dressings on orchard areas in grass.

A temporary interruption occurred at the beginning of these experiments, which may be explained as follows: The first (1912) application of fertilizers, as in all the Station's initial orchard fertilization experiments, was made in early May just after the petals of the blossoms had fallen. Already, in various other tests of this nature, application at this time in the season had proved of remarkable benefit to the succeeding year's crop, but no material increase in yields had been obtained, or were expected, for the reason in which the first application was made. Only a marked improvement in vigor in tree growth and foliage development and a prolific setting of fruit buds for the following season of 1913 were in anticipation as the result of first treatment in 1912. However, the spring of 1913 brought the serious freeze which destroyed practically all the newly-set fruit in the Dyar test plots. Hence the results of the initial fertilization of 1912 could not be measured in 1913.

Beginning with the season of 1914, the date of application of fertilizers to all test orchards was changed to April—about 1 month earlier—or at the time the first pink of the blossom buds is beginning to show. Yields were corrected to full stand of 12 trees per plot.

Fertilization with and without mulching with material from outside sources.—One of the interesting features of the test work in the Dyar orchard was the comparison of the usual formula 5-5-2½ pounds per tree of nitrate of soda, acid phosphate and muriate of potash applied on a mulch of straw maintained in circular or "belt" form under the outer extremities of the branches, with double quantity 10-10-5 pounds per tree fertilization with the same chemicals distributed evenly over each tree-square of ground with-

PLAN OF FERTILIZING THE DYAR ORCHARD

Plots	* A	B	C	* D	E	F	G	* H	I
Fertilized with	5 lbs. nit. soda, 10 lbs. phos., 2½ lbs. muriate potash per tree-square	10 lbs. phos. per tree-square	10 lbs. nit. soda, 10 lbs. phos., 5 lbs. mur. potash per tree-square	2½ lbs. nit. soda, 5 lbs. phos., 2½ lbs. mur. potash per tree on mulch	5 lbs. nit. soda, 5 lbs. phos , 2½ lbs. mur. potash per tree on mulch	Nothing	10 lbs. tankage, 10 lbs. bone, 5 lbs. mur. potash per tree-square	10 lbs. phos. per tree-square	5 lbs. nit. soda, 10 lbs. phos., 5 lbs. mur. potash per tree-square
1913	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*	*Pounds*
Apples†	......	......	......	......	......	......	......	......	......
Grass	837	837	837	......	......	205	417	417	417
1914									
Apples	5,712	5,348	6,300	5,922	6,986	2,828	3,640	4,102	4 704
Grass	493	336	667	......	......	81	363	337	655
1915									
Apples	4,484	3,990	7,574	5,124	6,440	1,260	4,144	3,192	4 998
Grass	600	204	776	......	......	60	276	285	636
1916									
Apples	5,180	6,440	6,090	6,300	8,540	3 220	5 180	5 460	6,020
Grass	571	636	724	......	......	163	732	542	681
1917									
Apples	1 793	1,260	3 675	1,344	1,527	42	1,512	1,527	2,706
Grass	492	483	592	......	......	134	789	357	487
Totals for 5 years:									
Apples	17,169	17,038	23,639	18,690	23,493	7,350	14,476	14,281	18,428
Grass	2,993	2,496	3,596	......	......	643	2,577	1,938	2 876
Av. barrels per acre per year for 5 yrs. (4 crops)	85.5	85.2	118.1	93.4	117.4	36.7	72.3	71.4	92.1
Av. pounds mulch per acre per year for 5 years	2,091	1,747	2,515	......	......	449	1 801	1,352	2 011

*For the purpose of observing effects of lessening the quantity of certain elements of plant food, dropping them out altogether, or substituting one form of plant food for another, embracing the same element, the following changes were made after beginning work in the Dyar orchard:

1. Rows A and B, in the years 1912-13, were uniformly fertilized with a 10-10-5 pounds per tree, nitrate-phosphate-potash mixture (the same as continued on Row C throughout the test), but were changed in the years 1914-'15-'16-'17 to the formulas given under A and B.
2. Row D, in the years 1912-13, was fertilized with a 5-5-2½ pounds per tree, nitrate-phosphate-potash mixture (the same as continued on Row E throughout the test), but was changed in 1914-'15-'16-'17 to the formula given under D.
3. Rows H and I, in the years 1912-13, were fertilized uniformly with a 10-10-5 pounds per tree, tankage, bone and potash mixture (the same as continued on Row G throughout the test), but were changed in 1914-'15-'16-'17 to the formulas given under H and I.

†Fruit all destroyed by cold in May. No records obtained.

out mulching with material from outside sources. By referring to the table of figures it will be found that these two methods and rates of fertilization embraced in Plots C and E, gave decidedly higher yields of fruit than any of the other test plots in the series, producing, respectively, at the rates of 118.1 barrels and 117.4 barrels per acre per year for the 5 years, with only four crops in that period. The comparative cost of these two methods and rates of fertilization was discussed to some extent in a partial report on the Dyar orchard operations, in Bulletin 301. (Figs. 15 and 16.)

A cost comparison of this particular nature really is an unsatisfactory one to attempt for the following reasons: (1) That the price of straw varies so greatly in different localities, and from year to year, as also do the distances and roadways over which the mulching material is transported; (2) that wet, moist, discolored, moldy or otherwise damaged and unmarketable straw is just as desirable for mulching as the clean, baled product; (3) that almost any kind of waste, damaged vegetable matter such as swamp-grass, old hay, corn stover, soybean-, cowpea-, or clover-haulm may be used with very satisfactory results as mulching material for the orchard; (4) that these different substances vary widely in their respective manurial value as decomposition in time renders the plant food within them available to growing trees or plants. In fact, in a farming community it will rarely be found necessary to purchase clean, marketable and usually high-priced straw or other forage to be used for mulching.

Beginning with medium-sized apple trees, ranging from 15 to 20 years of age, a bale of straw (from 80 to 100 pounds), or a similar quantity of loose material, per tree, will constitute a fair initial mulch when properly distributed in a circle or belt under the outer ends of the branches. An additional bale of straw or its equivalent in quantity per tree per year, or even every 2 years, with the annual addition of such vegetation as may be produced by and clipped from the spaces between the trees will gradually accumulate a soil covering of protective, decayed vegetable matter that will not only be beneficial as a moisture-holding factor but, in time, of more or less value as a source of plant nourishment.

The purpose of comparison of Plots C and E was this: To determine whether the extra 5-5-2½ pounds per tree of chemicals in the double quantity, or 10-10-5 pounds per tree per year, where the plant food was distributed evenly over the entire tree-squares, would prove as satisfactory and profitable as the usual

Fig. 15.—Production in 1914 of two rows of Ben Davis containing 12 trees each. Row at left, fertilized in 1912-13-14 with a 5-5-2½ pounds per tree nitrate-phosphate-potash mixture applied in connection with one bale of straw per tree annually, produced 49 barrels of large, marketable apples. Row at right, unfertilized, produced 20 barrels.

Fig. 16.—Production in 1915 of same two rows shown above, same treatment having been continued. Yield of fertilized row 46 barrels; of unfertilized row 9 barrels.

5-5-2½ pounds per tree per year formula where this quantity of chemicals was applied on a circular mulch of straw under the "drip" of the branches.

Our observation is that in a term of years, considering the widely differing cost of various mulch materials, the various distances and kinds of roads over which these bulky materials have to be hauled and their careful placement about the trees, the average cost of the two schemes of fertilzation will be very nearly equal. We have calculated these costs under many conditions and have made many estimates in which recently fluctuating prices of chemicals, and diverse materials for mulching, were taken into consideration. With these facts in mind it is both surprising and pleasing to note that the difference in the yields of apples per acre per year, between Plots C and E, for the 5-year period, was less than 1 barrel of fruit. This difference might vary, of course, in different orchards, and even in other comparisons of similarly paired plots in the same orchard; for unvarying uniformity of soil and size and degree of vigor of trees, in the hilly sections of Ohio or elsewhere, is a condition practically impossible to find in any considerable block of trees.

However, aside from the quite similar cost of treatment and yields of fruit under the two plans of fertilization now under discussion (Plots C and E), we have an additional result from the 10-10-5 pounds per tree per year fertilization which is remarkably gratifying and worthy of special consideration, namely: By the double-quantity, all-over fertilization we have secured not only yields of fruit equal to those obtained by a combination of the lesser rate of fertilization with mulching with material from outside sources, but have at the same time produced between the trees, on the orchard soil itself, in the form of finer, better grasses, mulching material at the rate of 2,515 pounds, sun-dry weight, per acre per year, or 59.8 pounds per tree-square per year. These grasses as the direct result of such fertilization promptly replaced the former light covering of native weeds and poverty grass. This vegetation annually clipped and permitted to lie on the ground, rapidly accumulated a soil covering superior in its eventual manurial value to an equal weight of wheat or oat straw.

What about mulching without fertilization?—Years of observation of the effects from mulching trees with straw or other similar material, under various soil conditions, well justifies conclusions which may be stated as follows: By far the more important office of a mulch, as demonstrated in the Ohio Station's orchard fertilization work of recent years, is its helpfulness in conserving soil moisture about the trees, enabling the applied, readily-available nitrogenous plant-food to exert its maximum influence. The quickly-soluble and promptly-available nitrogenous fertilizer is the only element that has greatly increased the vigor and fruitfulness of apple trees on the thin, poor upland soils of Ohio. The other important elements of plant food—phosphorus and potassium—of course play their parts in tree development and fruit production, but their effects have been such as have had to be determined by careful weights rather than measured at a glance by the eye as can

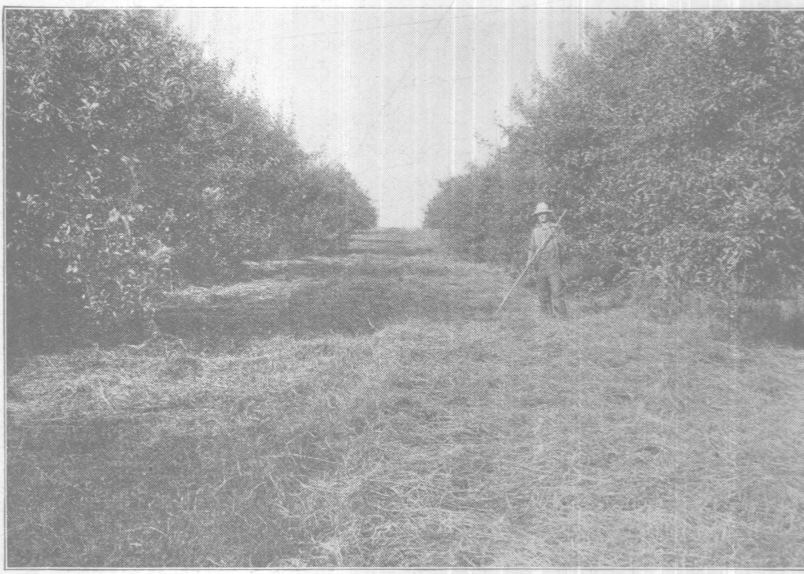

Fig. 17.—The row at the right is Plot C fertilized with the double-quantity or 10-10-5 pounds per tree per year nitrate-phosphate-potash formula applied over the tree-squares of ground. Note the heavy soil covering or mulch of grass produced by this heavier rate of fertilization. During the 5 years' test, Plot or Row C (12 trees) yielded 168.8 barrels of apples.

the results of the use of nitrogen. In other words, our humus- and fertility-depleted upland soils are in very much greater need of nitrogenous plant food than of phosphorus and potassium, so far as tree growth and fruit production are concerned.

Straw contains some nitrogen, therefore possesses fertilizing value for use as a mulch. Roughly calculating we may find that 160 pounds of wheat straw, or 100 pounds of oat straw, sun-dry weight, contain about the same quantity of nitrogen, by weight, as 5 pounds of nitrate of soda or 3⅘ pounds of sulphate of ammonia.

But the nitrogen in the straw is held in the raw, coarse vegetable fiber, and the nitrates are not available for plant food until the straw is fully decomposed and its substances well incorporated with the surface soil beneath the outer branches of the apple trees. This process where there is a hard, humusless, lifeless soil beneath the straw requires years of time. Even stable manure applied as a mulch under such conditions at the rate of from 300 to 500 pounds per tree per year has been noted to require from 3 to 5 years to get into such action that its effects are comparable with those of nitrate of soda within a single year.

Under more favorable soil conditions, we are prepared by experience to admit that a mulch of straw will produce effects similar to those of a moderately prompt-acting nitrogenous plant food, because of its promotion of conditions within the soil area thus covered for a more rapid liberation of nitrates from organic or vegetable matter in the soil. However, in very thin, poor, compact, lifeless soil, such as abounds in the long-tilled and persistently-cropped hilly sections of southeastern and southern Ohio, there is practically no humus, organic or nitrogenous matter remaining from which nitrates may be liberated even under the most generous mulching. Hence the benefits of a mulch, under such conditions, are for years limited principally to its moisture-conserving influence.

Effects of reduction of plant food after initial applications of standard and double-quantity formulas.—Plots D and E were fertilized in the years 1912-13 with the formula of 5-5-2½ pounds per tree of nitrate-phosphate-potash mixture (Plot D being mulched with straw as was Plot E). In 1914-'15-'16-'17 the quantity of nitrate was decreased one-half, or to 2½ pounds per tree on Plot D, while the standard formula was continued throughout the period of the test on Plot E. The reduction in yield of Plot D by cutting down the nitrate to one-half the usual quantity was at the rate of 24 barrels of apples per acre per year.

Plots A and C were fertilized in 1912-13 with the double-quantity formula of 10-10-5 pounds per tree of nitrate, phosphate and potash, respectively, applied evenly over the tree-squares of ground. In 1914-'15-'16-'17 the quantity of nitrate was decreased one-half or to 5 pounds per tree-square on Plot A, while the double-quantity formula was continued throughout the period of the test on Plot C. The reduction in yield of fruit on Plot A by cutting down the quantity of nitrate 50 percent was at the rate of 32.3 barrels per acre per year. The reduction of grass or mulch material produced on the tree-squares of Plot A at the same time was at the rate of 424 pounds per acre per year.

Effect of changing from tankage and bonemeal to nitrate and phosphate.—Plots G and I were fertilized in the years 1912-13 with 10-10-5 pounds per tree of tankage, bonemeal and muriate of potash, respectively, applied uniformly over the tree-squares of ground. In 1914-'15-'16-'17, on Plot I, 5 pounds of nitrate and 10 pounds of phosphate per tree, were substituted for the original 10-10 tankage-bone formula, which was continued throughout the period of the test on Plot G. The gain by this change was 19.8 barrels of apples and 210 pounds of mulching material per acre per year on Plot I.

In connection with this record of results of substitution of mineral sources of nitrogen and phosphorus for the animal sources of the same elements, the following question often has been asked by orchard owners: "Can we not successfully use in the place of nitrate of soda and acid phosphate similar quantities by weight of tankage and ground bone, thereby providing much more substantial, enduring sources of nitrogen and phosphorus for the trees?"

A comparison of results obtained in Plots C and G will suggest a conservative answer to the above question—these two plots having been treated with their respective designated formulas throughout the full period of the fertilization experiments. In this comparison it may be noted that the 10-10 pounds per tree per year application of nitrate of soda and acid phosphate (Plot C) gave a gain of 45.8 barrels of apples and 714 pounds of mulch material per acre per year over the use of 10-10 pounds per tree per year of tankage and bone on Plot G.

There are two outstanding reasons, however, why a comparison of equal weights of nitrate of soda and tankage as sources of the really determining element in orchard fertilization—nitrogen—is not a fair and equitable one: (1) Nitrate of soda carries, usually, about 16 percent of nitrogen, while tankage contains but from 6 to 8 percent. Ground bone carries a small amount of nitrogen, ranging from 2 to 4 percent. Therefore in 10 pounds of tankage and 10 pounds of bone as these were used in conjunction on Plot G, these fertilizing compounds together would contain hardly more than two-thirds the amount of nitrogen carried in the 10 pounds of nitrate of soda as applied on Plot C. (2) The nitrogen in nitrate of soda is quickly available while the nitrogen in tankage and bonemeal, when these are used as surface applications in grass-mulch orchards, is available very slowly.

One feature of the results of using tankage and bone as surface dressings, annually, in grass-mulch orchards, that has been clearly apparent and quite interesting, is the gradual, consistent increase and almost wonderful transformation of the vegetation of the orchard area thus treated. White clover, bluegrass, redtop and some timothy, without seeding, slowly but surely appeared, spread, thickened and eventually densely clothed the surface of the ground where these fertilizers were used. And it should be noted that in 1917—the closing year of the test in the Dyar orchard—the tankage-bone plot (Plot G) produced 789 pounds, or 65.75 pounds per tree-square of sun-dry vegetation.

Effect of dropping nitrogen after its use in the initial years of fertilization.—In 1912-13 Plots B and C were fertilized with the double quantity formula of 10-10-5 pounds per tree of nitrate-phosphate-potash mixture. In 1914-'15-'16-'17 the nitrate was dropped altogether from Plot B, while the double-quantity treatment was continued on Plot C throughout the period of the test. The yield of Plot B, by this omission of nitrogen, was reduced at the rate of 32.9 barrels of apples and 768 pounds of grass for mulch per acre per year. Now so long as we compare Plot B with Plot C the reduced production of Plot B seems quite logical—just about what we might expect under the circumstances. But when we turn from Plot B which had received only 10 pounds of acid phosphate per tree per year for the years 1914-'15-'16-'17, to Plot A on which 5 pounds of nitrate continued to be applied annually after its reduction from the original 10-10-5 formula, we discover that the yield of Plot A amounts to but six-tenths of a barrel per acre per year more than that of Plot B. Very naturally the first question suggested is: What is the use of applying 5 pounds of nitrate of soda per tree, year after year, if, after a few seasons' liberal use of this expensive nitrogenous compound at the outset, one can drop it out entirely and secure practically the same results by using thereafter, under the same cultural conditions, a generous, annual application of the comparatively inexpensive substance—acid phosphate? A snapshot conclusion such as that suggested above, would be deplorable and disastrous. Repeated tests and observations have shown that, in orchard fertilization, the effects of the application of nitrate do not carry over in a noticeably beneficial degree more than 1 year. And there was every evidence in the way of tree vigor and growth and appearance, and in abundant fruit production, that those trees in Plot B, notwithstanding that nitrate was entirely withheld from them in the years of 1914-'15-'16-'17, managed to obtain an annual supply of nitrogen from some source, sufficient to promote fruitfulness practically equal to that of Plot A on which was continued an annual application of 5 pounds of nitrate.

Now let us do a bit of horticultural detective service; for there is usually some good reason, however obscurely veiled by the intricate processes of nature, for seemingly freakish behavior of the "mystery" plot or plots likely to appear in any series of plots in fertilization experiments in orchard, field or garden.

In the first place may we bear in mind that the apple trees in this entire experimental block, at the beginning, were 14 or 15 years of age but low in vigor, stunted in growth and small for their age. They stood about 32 feet apart either way and it is quite safe to assert that there was yet no meeting, interlacing or overlapping of the feeding-root systems of the trees between the rows.

Next let us consider the fact that in 1912-13 Plots A, B and C were uniformly fertilized with the double-quantity, 10-10-5 nitrate-phosphate-potash mixture sown evenly over the tree-squares, or, in other words, uniformly over the entire surface of the orchard area occupied by these adjoining plots each of which consisted of a single row of 12 trees. From this heavy, uniform, nitrogenous fertilization in 1912-13, the trees in these plots promptly sprang into vigorous growth, rapidly increased in size and far outstripped in branch and feeding-root extension not only the check or unfertilized trees, but those fertilized with the 10-10-5 tankage-bone-potash mixture—Plots G, H and I.

Indeed such a marked and remarkable extension of branch and feeding-root growth as had taken place up to the time of the growing and fruiting season of 1914—the first fruiting season after the beginning of the test in this orchard—had resulted in the condition sooner or later inevitable, that the feeding-root systems of these highly-nourished plots of trees were gradually but surely threading their way across the plot boundary lines midway between the rows, and overlapping.

Under these conditions of the presence of abundant, readily-available nitrogenous plant food in the outer two of three tree rows, or plots, separated by spaces of but 32 feet, what will be the result if, from the intervening or center row, the invigorating nourishment for a period enjoyed is suddenly withheld and persistently denied, while the rows on either side continue to receive the plant food sown evenly and to lines midway between the hungry row and those so closely paralleling it on either hand? What would half-famished representatives of the furred and feathered families do under the circumstances with tempting food nearby and a rapidly developing ability of claw or wing to reach beyond their legitimate confines and help themselves? What, indeed, would be the natural impulse of those trees in Plot B, whose far-reaching terminal feeding-rootlets finally pushing out beyond the boundary lines of the plot within which they were supposed to seek nourishment, should find themselves within soil rich in the elements of their favorite foliage-, wood- and fruit-producing food? Would not these trees "help themselves" at the expense of their well-supplied neighbors? There is not the slightest doubt of this—even if they had been some kind other than Ben Davis—a variety notable for its ability to take pretty good care of itself under difficult conditions. But even Ben Davis has suffered from starvation in the Buckeye state.

Plots G, H and I were fertilized uniformly in the years of 1912-13 with the 10-10-5 tankage-bone-potash mixture. In 1914-'15-'16-'17 the treatment of Plot H was changed to 10 pounds per tree of acid phosphate alone (the same treatment as accorded Plot B in the same years), while the 10-10-5 tankage-bone-potash treatment was continued on Plot G throughout the test. Now, comparing the fruit product of Plot H with that of Plot G, we find that the reduction in yield of Plot H, by withholding the tankage as the source of nitrogen, amounted to but nine-tenths of one barrel of apples and 449 pounds of mulch material per acre per year. The reduction of the yield of Plot H, however, when compared with Plot I on which 5 pounds of nitrate of soda per tree were applied in 1914-'15-'16-'17, as the source of nitrogen, amounted to 20.7 barrels of apples and 659 pounds of mulch material per acre per year.

The trees in Plots G, H and I in 1912-13 made but little increase in size as the result of fertilization with the tankage-bone-potash mixture (differing greatly in this respect from Plots A, B and C fertilized during the same years with the double-quantity nitrate-phosphate-potash formula). Even within the entire period of the test the increase in size of the trees in Plots G and H was not greatly in excess of those in the unfertilized or check plots, although the yields were just about double. Hence there was slight, if any, indication that the trees in Plot H in which fertilization was limited to the application of 10 pounds of acid phosphate per tree during the years 1914-'15-'16-'17, benefited by their situation between two plots receiving nitrogenous plant food throughout the period of experimentation (as did Plot B). Indeed the trees in Plot H had not enlarged in growth and feeding-root extension to a degree that the roots were at all likely to feed beyond or outside the boundary lines of Plot H.

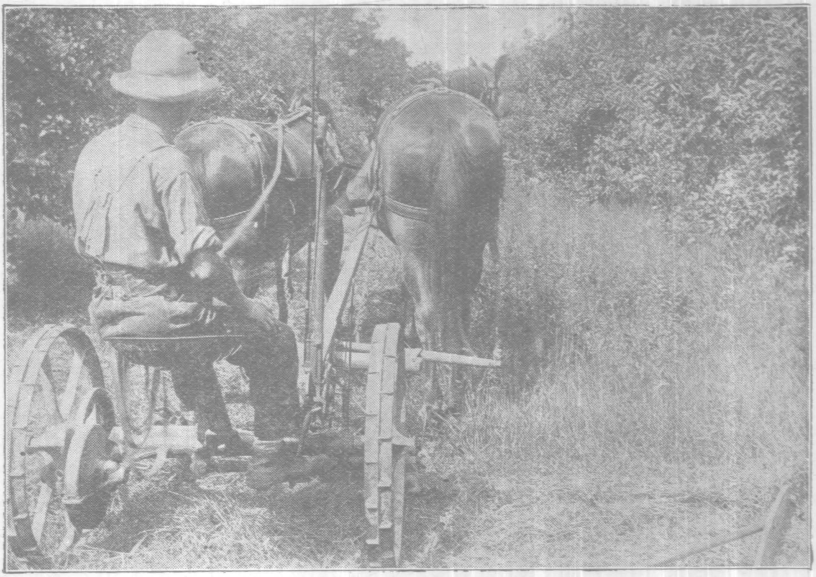

Fig. 18.—Mowing 714 pounds per acre, sun-dry weight, of mixed weeds and poverty grass, in 1913, in the unfertilized or "check" plot.

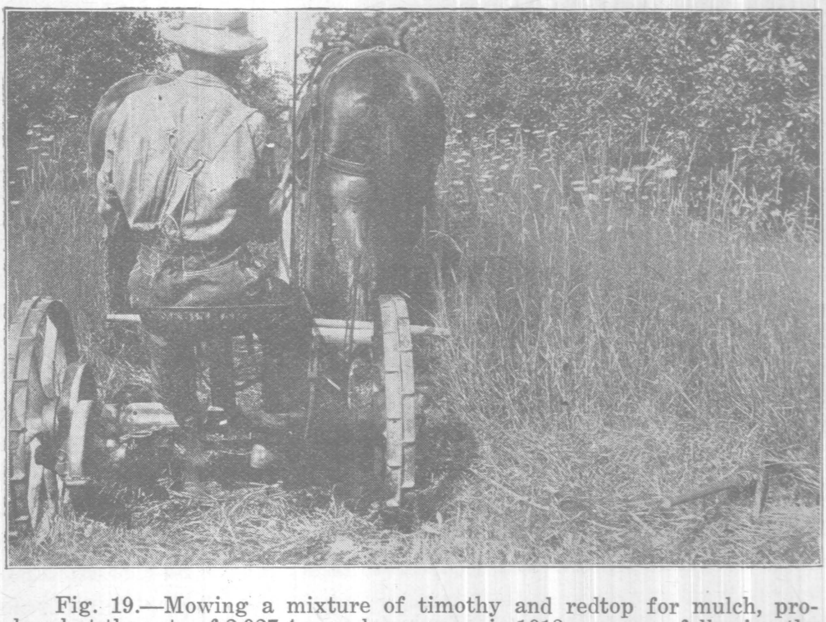

Fig. 19.—Mowing a mixture of timothy and redtop for mulch, produced at the rate of 2,927.4 pounds per acre, in 1913, one year following the first application of the double-quantity 10-10-5 nitrate-phosphate-potash formula. No seeding done. A few ox-eye daisies yet survive the crowding.

Nitrogenous and phosphoric plant foods as influencing the character of vegetation in the Dyar orchard.—In no orchard fertilization experiment conducted by the Ohio Experiment Station in southeastern Ohio were the peculiar influences of nitrogen and phosphorus in the development, respectively, of grasses and clovers where, previously, the thin soil covering was apparently composed of a mixture of only native weeds and poverty grass, more clearly demonstrated than in the Dyar orchard in Washington County.

During the course of the experiment, Plots B and H which in the years 1914-'15-'16-'17 were fertilized with 10 pounds per tree of acid phosphate alone, became covered with a mass of white clover beautiful to look upon. Plot G which annually received the 10-10 pounds per tree-square mixture of tankage and bone during the full time of the experiment, gradually developed a dense matting composed of a fine mixture of grasses and white clover. Plot C fertilized throughout the test with the double-quantity or 10-10-5 pounds per tree-square of the nitrate-phosphate-potash mixture, respectively, was a marvel because of its heavy yields of timothy, redtop, bluegrass and June grass. (Figs. 18 and 19.) While this plot, it is true, annually received heavy applications of acid phosphate in connection with the nitrate but little clover developed; but this failure of clover was clearly due to the rampant growth of the grasses, the height and denseness of which choked and smothered the clover to the extent that it could not possibly survive the competition.

SUMMARY

RESULTS AND OBSERVATIONS IN THE BENEDICT ORCHARD, COVERING A PERIOD OF 5 YEARS

1. Cost of "cultural work" in the grass-mulch section averaged $2.65 per acre per year.

2. Cost of cultural work in the tillage-cover-crop section averaged $17.09 per acre per year.

3. Under uniform fertilization throughout both sections, the grass-mulch method of culture gave an average gain of 1.9 barrels of apples, or a cash gain of $20.52 per acre per year, over the tillage-cover-crop system.

4. Unfertilized plots under tillage and cover-cropping gave an average gain of 15.6 barrels of apples, or cash gain of $35.48 over the unfertilized plots in the grass-mulch section. But it should be borne in mind that the latter-named plots remained in their former state of neglect with the exception of spraying, which was uniform over the whole orchard.

5. Grass-mulch culture plus fertilization with quickly available nitrogenous plant food, gave an average gain of 22.2 barrels of apples, or a net cash gain of $71.48 per acre per year over the tillage-cover-crop system without fertilization.

6. The cost of the grass-mulch method of orchard culture, plus fertilization with the standard 5-5-2½ pounds per tree per year nitrate-phosphate-potash formula, is practically the same as that of the tillage-cover-crop system without fertilization.

7. Under the tillage-cover-crop system, fertilization with nitrogenous plant food gave a gain of 20.3 barrels of apples, or a net cash gain of $50.96 per acre per year, over no fertilization under the same cultural conditions.

8. Under the grass-mulch method of culture, fertilization with nitrogenous plant food gave a gain of 37.8 barrels of apples, or a net cash gain of $106.96 per acre per year, over no fertilization in the same section.

9. Apples grown under the grass-mulch plan of culture are slightly smaller, but are finer in texture, firmer, higher in color and superior in keeping qualities to those produced under tillage and cultivation.

10. The orchard work was performed with cleanliness and comfort at all seasons of the year in the grass-mulch section. This cannot be said of the tillage-cover-crop division where, at various inopportune times, mud abounded in all its southern Ohio glory.

11. There is little difference in results, so far as fruit production is concerned, whether the fertilizer be applied in circles beneath the outer extremities of the branches of trees or over the entire tree-squares of ground.

12. The advantage of the tree-square or "all over" plan of applying the fertilizer in grass-mulch orchards is that, in addition to increasing fruit production, the vegetation of the orchard ground is likewise increased, affording a greater quantity of mulch material. This increase, in the Benedict orchard, amounted to 1,650 pounds per acre per year, sun-dry weight, as compared with the yield of unfertilized plots.

13. The standard 5-5-2½ pounds per tree per year, nitrate-phosphate-potash formula, applied over tree-squares, promptly developed without seeding a dense soil covering of grasses and red and white clover where, previously, only mixed weeds, poverty grass and sedge prevailed.

14. Broom-sedge, by the annual nitrate-phosphate treatment, was cut out almost as cleanly from the fertilized plots as it could have been with a mowing machine. This was a strikingly suggestive discovery in that section where broom sedge is so freely spreading over the thin upland fields of grass or pasture.

15. Pruning, spraying and fertilization transformed the Benedict orchard from a sickly, barren, discouraging, disappointing farm encumbrance and source of neighborhood and sectional perplexity, into a fruitful, vigorous, profitable little plantation that promises abundant returns for many years to come.

RESULTS AND OBSERVATIONS IN THE DYAR ORCHARD, COVERING A PERIOD OF 5 YEARS

1. Quickly-available nitrogen is clearly the determining element in successful orchard fertilization on thin, poor, upland soils such as abound in the hilly regions of southern Ohio; but phosphorus is beneficial also and may well be used in conjunction with the nitrogenous applications. Potash has given little or no returns under the conditions named above.

2. Annual applications of 5 pounds per tree per year each of nitrate of soda and acid phosphate used in connection with a mulch of straw maintained by annual or biennial applications of one bale per tree gave practically the same results as the use of 10 pounds per tree per year each of nitrate and phosphate applied evenly over the tree-squares without a mulch brought in from outside sources.

3. The 10-10 pounds per tree per year, nitrate-phosphate-mixture above mentioned, however, in addition to the greatly increased fruit product, gave a gain of 2,066 pounds per acre per year, sun-dry weight, of grasses for mulch, as compared with the yield of mixed, native weeds and poverty grass in the unfertilized plot.

4. Annual applications of the 5-5-2½ pounds per tree, nitrate-phosphate-potash mixture, used in conjunction with a mulch of straw, gave a gain of 24 barrels of apples per acre per year, over a 2½-5-2½ pounds per tree formula of the same fertilizers.

5. On soil that is not deficient in organic or vegetable matter, a liberal mulch of straw alone will assist in producing effects similar to those following the application of a moderately prompt-acting nitrogenous plant food, because such a mulch affords conditions under which there occurs a hastened liberation of nitrates from the organic matter in the soil. But on thin, compact, humusless, lifeless soil—soil in which no organic matter is present—nourishing effects of a straw mulch do not soon materialize.

6. On thin, poor, compact soil in which there is no vegetable matter, therefore, the more important office of a mulch of straw or similar material is its helpfulness in conservation of soil moisture.

7. Animal sources of nitrogen and phosphorus (tankage and bone), because of their comparatively slow availability as surface applications in grass-mulch orchards, are by no means as satisfactory as equal weights (or half-weight) of mineral compounds of these elements as represented by nitrate of soda and acid phosphate.

8. Tankage and bone exert a tardy but gradually increasing beneficial effect on the vegetation of the orchard area, and for this purpose, eventually, may not be surpassed. But these substances are entirely too slow in their influence on the trees to be desirable as orchard plant food under poor soil conditions where prompt results are sought. Incorporated with the soil by the tillage-cover-crop system of orchard culture, tankage and bone are ideal.

9. The dropping out of nitrate after heavy initial use of same in orchard fertilization will soon result in a material reduction in the vigor of the trees and yield of fruit as compared with plots upon which nitrogenous applications are continued. The "hold-over" effects of nitrate should not be depended upon for more than 1 year for each application.

10. Where quickly-available nitrogenous fertilizers are used over entire tree-squares of ground, in plots separated only by the usual width of the spaces between the rows, there will in time occur, through the great enlargement of the feeding-root systems of the trees, "pilfering" of plant food by one plot from another, thus in a measure complicating and disturbing results. Beginning with trees 15 to 20 years of age, even if these be stunted and small for their age at the outset, it is doubtful whether quickly-available nitrogenous fertilization can be conducted longer than from 3 to 5 years without serious "cross-feeding" by trees of different fertilized plots, unless the plots in each case be separated by an untreated or "neutral" row.

11. The influence of nitrogen and phosphorus in development of different forms of vegetation (grasses and clovers, respectively) for mulching purposes, in grass-mulch orchards, was clearly marked in the Dyar orchard—as clearly, indeed, as in the Benedict plots at Vincent, Washington County, or in the Porter plots in Muskingum County as mentioned in a former bulletin.

12. In the Dyar experiments we have an excellent illustration of the fact that pruning, spraying, fertilization and mulching not only will promptly promote vigor and fruitfulness in a hungry, uncared-for orchard supposed to be of no value above that of thin-soiled ground for pasture purposes, but that such an orchard may be developed into a valuable farm institution—one capable of home-building, life-work determination and pleasant and enduring business.